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HIGH-TEMPERATURE DRYING OF 7/4 YELLOW-POPLAR FLITCHES FOR S-D-R--ETC(U)
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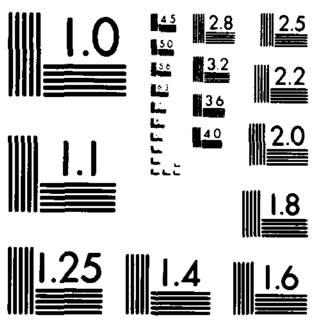

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United States Department of Agriculture

Forest Service

Forest Products Laboratory

Research Paper

FPL 365

February, 1980

High-Temperature Drying Of 7/4 Yellow-Poplar Flitches For S-D-R Studs

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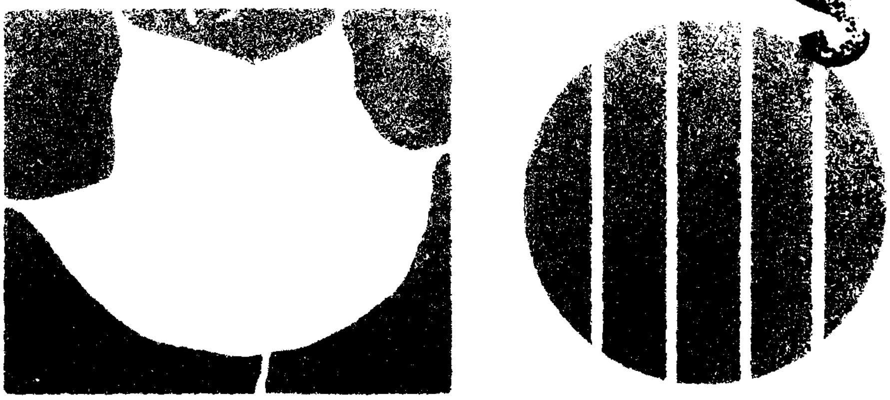

Abstract

Yellow-poplar was dried as 7/4 flitches at high temperatures and subsequently ripped into studs to meet National Grading Rule Standards for STUD grade. The effects of growth stresses in these flitches from smaller logs appear to be minimized by this process. Dry bulb temperatures from 235° to 295° F were explored in five drying trials. Best results were by drying for 28 hours at 235° F, followed by an equalizing period of 48 hours at 200° F and an equilibrium moisture content of 10 percent.

United States Department of Agriculture
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Introduction

S-D-R, short for Saw, Dry, and Rip, is a technique whereby logs are live-sawn through and through on the same plane into 7/4 flitches. The flitches are rough edged to make a compact kiln load and dried to an average moisture content of about 10 to 12 percent. The dried flitches are then ripped into studs.

As the S-D-R concept[2] [3] was being formalized at the Forest Products Laboratory, it became clear that an integral part of this concept was development of a workable, dependable high-temperature kiln schedule.

This paper reports the results of a study to develop a suitable high-temperature schedule for 7/4 (1-¾-in.-thick) random width yellow-poplar flitches. The objective was to develop drying schedules that would result in the least degrade as determined by visual means. The effect of drying schedules on strength was not evaluated. The suggested schedule is being tested further in a larger scale pilot study.

Materials and Methods

Log Selection and Processing

Logs were selected from woods-run trees, 8 to 12 inches in diameter at breast height, from either the Hoosier National Forest in central Indiana or the Bent Creek Experimental Forest near Asheville, N.C. Of the 22 logs from North Carolina used in this study, 13 were from trees that had been felled 4 to 5 months previously in a thinning operation. These trees had been laying on the ground in the woods so there was no reason to believe that the moisture content of their logs would be substantially different than the logs freshly cut later.

At Forest Products Laboratory the logs were segregated by small-end diameter and log position (butt, middle, top). Logs were then live-sawn into 7/4 flitches. Flitches were edged to provide a more compact kiln load and end-trimmed to a length of 97 inches. Each kiln load represented all diameter classes and log positions.

Drying Techniques

An aluminum prefabricated steam-heated kiln capable of high-temperature drying was used for all trial runs. All kiln runs contained about 200 to 350 board feet, with pile widths varying from 5 to 6 feet and air speeds of 1,000 to 1,100 feet per minute. Stickers, ¾ inch thick, were on 2-foot centers. A top load of about 25 pounds per square foot was applied by using iron bars to simulate the weight of a larger load. Kiln set point conditions were achieved in 1 to 2 hours in all runs. Moisture content while drying was monitored by the standard sample board technique. The target moisture content was 12%, with a maximum of 15% and a minimum of 8 to 10%.

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[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.
[2] Maeglin, R. R., 1978. Yellow-poplar studs by S-D-R. Southern Lumberman 2944(237):58-60.
[3] Hallock, H., and E. H. Bulgrin. 1978. A look at yellow-poplar for studs. USDA For. Serv. Res. Note FPL-0236, For. Prod. Lab., Madison, Wis.

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Trial Schedules Used

Work in progress on high-temperature drying of 4/4 hardwoods indicated that dry bulb temperatures of about 235° F, with accompanying high wet bulb temperatures of 180° to 190° F, gave acceptable quality in many species. Thus Trial I used a dry bulb of 235° F with accompanying wet bulb of 190° F.

The plan was that, from results in Trial I, conditions would be modified in future trials to optimize drying and quality. Five trial schedules were finally tried (table 1).

Table 1.—The five trial schedules used for drying yellow-poplar flitches

Trial	High temperature				Equalizing[1]				Total kiln residence time
	Dry bulb	Wet bulb	Time	Fan reversal	Dry bulb	Wet bulb	Time	Fan reversal	
	°F	°F	h	h	°F	°F	h	h	h
I	235	190	24	6	190	178	66	6	90
II	295	200	18	6	190	178	56	6	74
III	230 290	190 190	4 8	4	195	183	20	6	32
IV	260	190	20	[2]4	200	188	52	6	72
V	235	190	27	[2]4	200	188	41	6	68

[1] At 10% EMC.
[2] Every 4 h for first 8 h, then at 6-h intervals thereafter.

Flitches to Studs

After drying and cooling, moisture content of each flitch from Indiana-grown material was checked at nine locations with an electric resistance moisture meter using a two-insulated pin electrode, driven to ½-inch depth. These locations sampled variation across the width and along the length of the flitch. North Carolina stock was similarly checked at three locations along the length. The flitches were then straight-line-ripped into nominal 2-by 4-, 2- by 3-, and 2- by 2-inch studs, with emphasis on 2 by 4's. All pieces were dressed to standard American Lumber Standard sizes. After dressing, studs were measured for crook, bow, and twist to the nearest 1/32 inch. Acceptance as studs was determined using the National Grading Rule (NGR) for dimension lumber, STUD grade.

Table 2.—Results of trial schedules for 7/4 yellow-poplar flitches

Trial	High temperature	Equalizing	Total time	Moisture content			
				Sample boards[1]			Resistance meter
				Initial range	Final range	Final $\bar{x}$	[2] $\bar{x}$
	°F	°F	h				
I	235-190	190-178	90	72-111	9.3-14.8	11.2	10.1
II	295-200	190-178	74	64-94	6.4- 7.0	6.7	7.5
III	230-190 290-190	195-183	32	47-99	6.8-19.1	12.1	11.9
IV	260-190	200-188	72	63-112	6.7-10.5	8.6	8.2
V	235-190	200-188	68	55-62	7.3-9.5	8.3	10.6

[1] 4 to 5 per run.
[2] Corrected for temperature and species as necessary.

Results and Discussion

Information on the initial and final moisture contents of the stock is listed in table 2.

Trial I

Average initial moisture content for five sample boards was 90%, ranging from 72% for an all-heartwood piece to 110.7% for a heart-sap piece containing pith. After 18 hours, at the first weighing, the average of five sample boards was 26.3%, ranging from 15.9% for a narrow (4-¾ in.) 90% sapwood piece to 32.6% for the piece initially at 110.7%. After 24 hours the average was down to 18.5%, with the driest sample at 10.8%. The kiln was then cooled for a short time to start the equalizing treatment—equilibrium moisture content (EMC) 10%, dry bulb 190° F.

After 48 hours from start up, the average moisture content was 14.8%, the driest board was 9.9%, but the wettest was still 21.2%. Equalizing continued until, at 90 hours, the wettest sample board had dropped to 14.8% and the kiln shut down. Average moisture content at that time was 11.2% with the driest reading being 9.3%.

After cooling for 4 to 5 hours, moisture content was measured with a resistance moisture meter using a two-insulated pin electrode driven to a depth of ½ inch. Data were taken on every flitch. Nine positions were sampled on each flitch— three positions across the width at each of three positions along the length. Based on these measurements, uncorrected for temperature and species, the average moisture content for the load was 13%, ranging from 9 to 22%.

While no internal temperature measurements were made, the assumption of 140° F was made for moisture content correction. The metered load average of 13% was corrected for temperature and species and a value of 10.1% found.[4] [5]

From this kiln charge, forty-three 2 by 4's, eighteen 2 by 3's, and twenty-five 2 by 2's were ripped. All 86 pieces met the NGR warp standards for STUD grade.

Surface of the rough flitches was slightly darker than usual, but this darkening was removed when studs

[4] James, W. L. 1975. Electric moisture meters for wood. USDA For. Serv. Gen. Tech. Rep. FPL-6. For. Prod. Lab., Madison, Wis.
[5] Delmhorst Instrument Company (no date). Owners manual, moisture detectors for wood. Boonton, N.J.

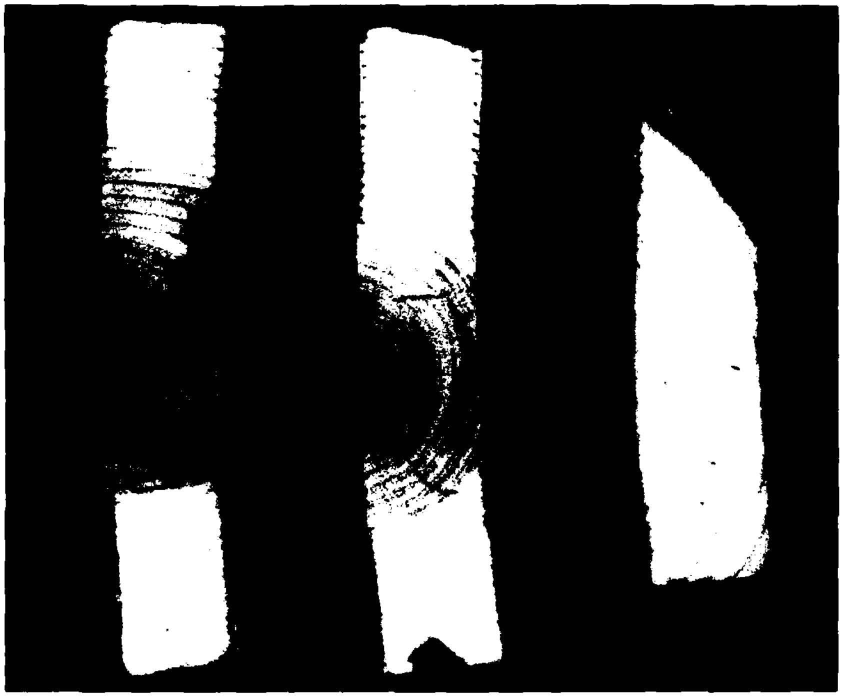

Figure 1.—Typical cross section of flitches dried by Trial Schedule I. (M 147 016)

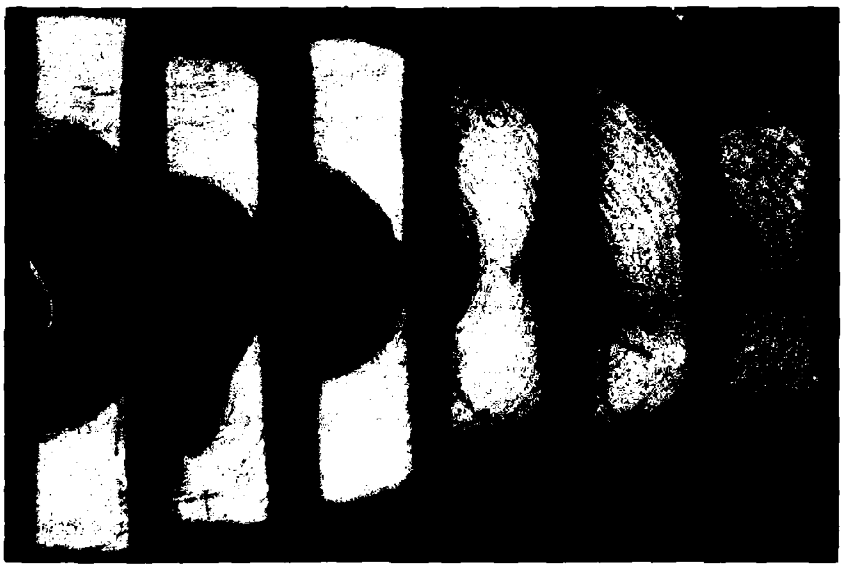

Figure 2.—Cross sections of flitches dried by Trial Schedule II. Note honeycomb in heartwood and sapwood and darkening of heartwood. (M 147 014)

were planed to final size. No collapse and only an occasional evidence of honeycomb was observed. Some idea of the bright interior color and quality is apparent in figure 1.

Trial II

Results from Trial I were considered quite acceptable and the schedule moderate. Therefore Trial Schedule II was more severe, near the maximum operating temperature of our kiln, using a dry bulb of 295° F and wet bulb of 200° F.

Average initial moisture content for the sample boards was 81.6%, ranging from 64.1% for a narrow all-heart piece to 93.8% for a narrow all-sap piece. The sample boards were first weighed after 18 hours, at which time the stock was virtually ovendry. Average moisture content for the sample boards was only 2.3%, with two sample boards having less than 1% and the maximum being 4.1%.

After cooling below 212° F, conditions in the kiln were set at 10% EMC to try to bring material back to our minimum goal of 8 to 10%. Following 30 hours of equalizing, the average was 5.9% and the spread between pieces was from 5.0 to 6.5%.

After 56 hours of equalizing treatment, the average for sample boards was 6.7% with the spread narrowed to 6.4 to 7.0%. The kiln was shut down at this time and material allowed to cool in the kiln because it is much more difficult to raise the moisture content than it is to lower it.

After cooling for 3 days, moisture content was measured at the ½-inch depth in the flitches as in Trial I. Though several individual readings of less than 5 (lower limit for meter) were recorded, the value of 5 was used in computing averages. Meter readings, uncorrected for species, averaged 7.3% with a range of 5.4 to 12%. No temperature correction was needed as stock had cooled to the ambient temperature of about 70° F. The metered load average of 7.3 was corrected for species to a value of 7.5%.

This kiln charge produced thirty-seven 2 by 4's, eighteen 2 by 3's, and twenty-three 2 by 2's. As in Trial I, all 78 pieces met the NGR warp standards for STUD grade.

A darkening in color occurred in virtually all pieces with heartwood (fig. 2). There was also considerable honeycomb in both heartwood and

Figure 3.—Severe honeycomb in heartwood of studs sawn from flitches dried by Trial Schedule II.
(M 147 015)

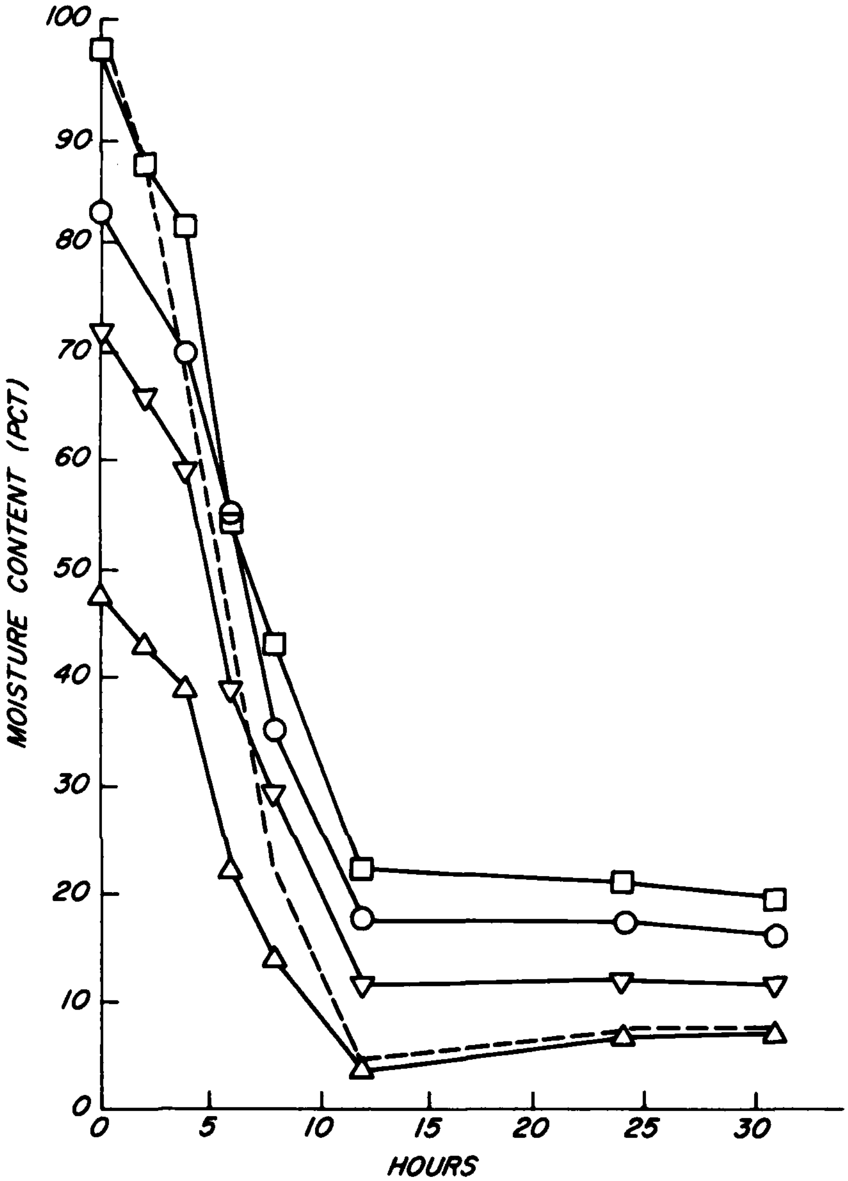

Figure 4.—Drying curves for Trial Schedule III. (Note large spread in initial MC and at end of run.).
(M 148 462)

sapwood. Although the effect of honeycomb on grade of the studs was not evaluated, honeycomb was visible on the surface of more than three-fourths of the 2 by 4's, about one-half of the 2 by 3's, and in about two-thirds of the 2 by 2's. In many cases the honeycomb was quite severe (fig. 3).

Trial III

The third trial was a two-stage drying regime using 230° F dry bulb temperature for 4 hours, then raising the dry bulb to 290° F for 8 hours. Equalizing time was only 20 hours, less than half that of other trial schedules.

Average initial moisture content for the five sample boards was 79.6% with the driest being 47.1% and the wettest 99.1%. This was the largest spread in initial MC of any of the five kiln runs (fig. 4). After 4 hours at 230° F (including about ¾ h for the kiln to reach 230° F), the average of the sample boards was down to 62.7% with a spread from 38.3 to 81.0%. At the completion of the high-temperature drying (12 h), the average was 11.8% but the spread was from 3.6 to 22.0%.

After equalizing at 10% EMC for 20 hours, the overall average of sample boards was 12.1% with a spread from 6.8 to 19.1%. The sample board with the highest moisture content, after 32 hours of drying, was a piece 8 inches wide with 50% heartwood containing the pith. The board consistently the driest was a 4-½-inch-wide, 85% sapwood piece.

Extending the equalizing time would have narrowed the difference between wettest and driest pieces. This equalizing period would normally have continued until the wettest board reached our predetermined

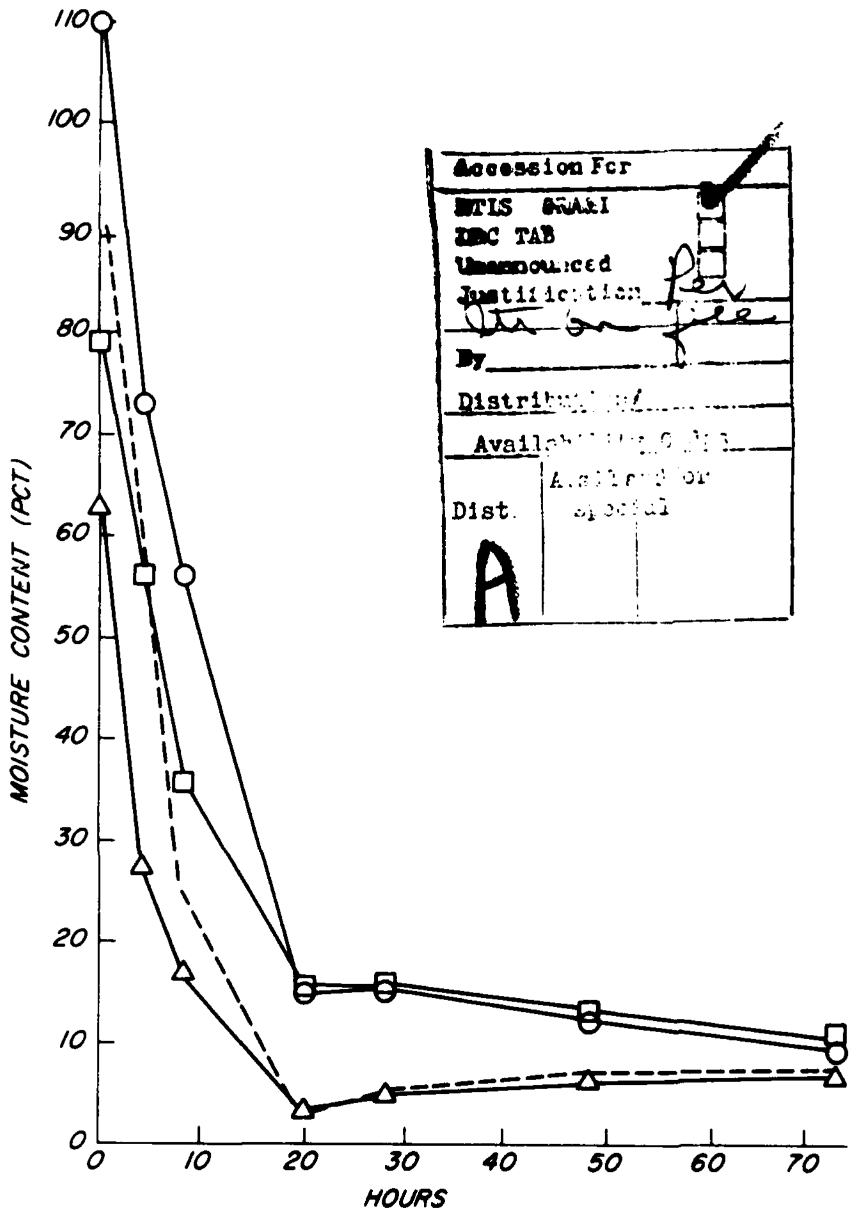

Figure 5.—Drying curves for Trial Schedule IV. (Note benefits of longer equalizing times.).
(M 148 463)

maximum allowable, 15%. However, we purposely shortened the equalizing period for this trial. Total elapsed time for this run then was only 32 hours.

The kiln charge, still stickered, was rolled out of the kiln and allowed to cool for 18 to 20 hours at room temperature. Moisture content was then metered at the ½-inch depth as in Trials I and II. Meter readings, uncorrected for species, averaged 10.9%, with a range of 5.8 to 17.1%. Occasional individual readings taken in heartwood portions were as high as 28 to 30%. At the low end, several individual readings in narrower sapwood pieces were as low as 6 to 7%. This wide spread reflects the short equalizing time employed. No correction for temperature was needed. The metered load average of 10.9 was corrected for species to a value of 11.9%.

Thirty-two 2 by 4's, twenty-four 2 by 3's, and twenty-five 2 by 2's were cut from this kiln load. As in Trials I and II, all 81 pieces were within the warp limitations to make the STUD grade. Slight darkening was noted. Honeycomb was observed on the surface in about one-third of the 2 by 4's, one-eighth of the 2 by 3's, and one-fourth of the 2 by 2's.

Trial IV

A dry bulb temperature of 260° F, about midway between the 235° F and 290° F, was chosen for this trial (table 1).

Four sample boards were used to monitor the trial; the average initial moisture content was 86.1%. (It was later determined that three sample boards were from freshly felled trees and one from a previously felled tree.) The driest sample was 62.6% and the wettest 112.2% (fig. 5). When weighed after 20 hours, the driest sample was down to 2.4% MC and the wettest at 15%, with an average of 8.9%. As in previous runs, an equalizing period at an EMC of 10% was initiated. After equalizing for 28 hours, the spread had narrowed to 6.2% and 13.1%; another 24 hours narrowed it further to 6.7 and 10.5%, with an average of 8.6%. The drying curves in figure 5 indicate the benefits of equalizing.

This load cooled for 4 days so no temperature correction was needed for meter readings. Only three meter readings were taken per flitch, primarily indicating variation along the length. Meter readings uncorrected for species averaged 7.8% with a range from 5.8 to 13.7%. The metered load average of 7.8 was corrected for species to a value of 8.2%.

The cut from this somewhat smaller charge was twenty-seven 2 by 4's, nineteen 2 by 3's, and nineteen 2 by 2's. All 65 were acceptable with the warp limitation for STUD grade. There was some interior darkening of the stock. Honeycomb (primarily in heartwood) was observed in ripping and surfacing the flitches. Two-thirds of the 2 by 4's and about one-half the 2 by 3's and 2 by 2's showed some evidence of honeycomb on the surface.

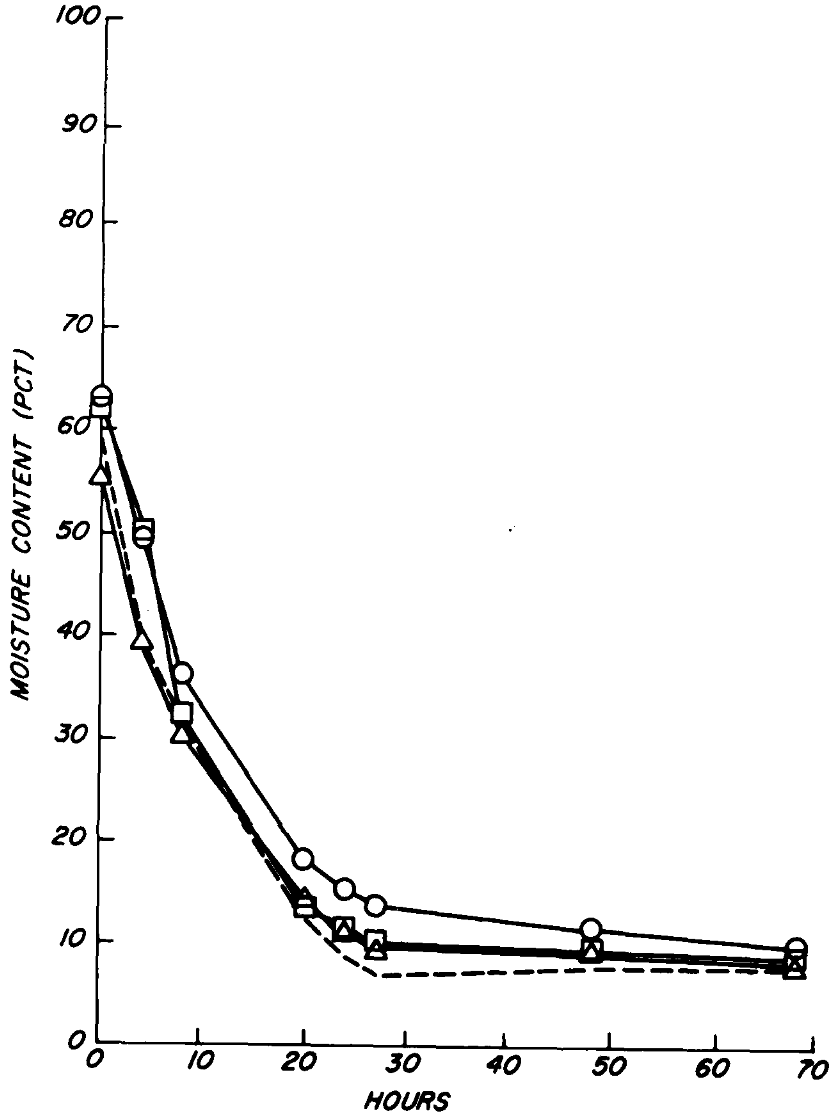

Figure 6.—Drying curves for Trial Schedule V. (M 148 461)

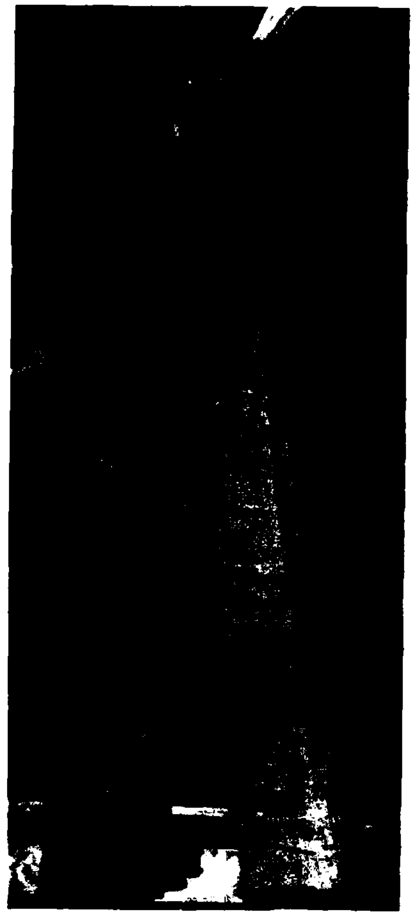

Figure 7.—Severe growth stresses produced this split, which lengthened during drying. (M 147 632)

Trial V

Trial Schedule V was a modification of Trial I, which was seen as the best of the four previous trials, because of the uniformity of moisture content and quality of the studs. Drying time at 235° F was lengthened and equalizing was done at somewhat higher temperatures. We later determined that, by chance, only one of the four sample boards was from a freshly cut tree and the remainder were from the previously felled trees. This probably accounts for the comparatively low average moisture content of the four samples and the narrow spread in MC between them.

The average initial moisture content was 59.6%, with the driest board at 54.6% and the wettest at 62.6%. After 20 hours, (fig. 6), the average had dropped to 14.4% with a spread from 12.1 to 18.0%. At 27 hours the average was 9.6% with the wettest board at 13.2% and the driest at 6.8%. The kiln was cooled and equalizing conditions of 10% EMC were established and held for 41 hours. This resulted in an average moisture content of 8.3% with a spread of 7.3 to 9.5%.

This run cooled for 3 days. Three meter readings were taken per flitch, as in Trial IV. Metered readings uncorrected for species averaged 9.8% with a range of 7.3 to 14.0%. The metered load average of 9.8% was corrected for species to a value of 10.6%.

From this smaller run of about 200 board feet lumber scale, twenty-four 2 by 4's, twelve 2 by 3's, and nine 2 by 2's were cut. One 2 by 4 exceeded the requirements for twist, therefore, only 97.8% of the 45 pieces met STUD grade. No interior darkening was noticed in processing this material. Minor honeycomb was observed in three of the 2 by 4's, five of the 2 by 3's, and two of the 2 by 2's.

Review of Trial Schedules

Of these five trial schedules, material from Trials I and V gave the best results based on uniformity of moisture content, brightness of color, and levels of drying defect such as checking, collapse, and honeycomb.

The equalizing portion of these schedules is intended to improve uniformity of moisture content between and within pieces. Equalizing times may vary depending on initial moisture content of the flitches, width of flitches, pile width, target moisture content, and acceptable spread between driest and wettest flitches. Where loads contain some very narrow flitches and moderate-to-very wide flitches with 50% or more heartwood, a shortening of the suggested equalizing period is not recommended. Longer equalizing times may also contribute to minimizing the effects of growth stresses.

Trial II did not appear favorable because of heavy honeycomb and darkening of stock throughout the piece as well as over drying. Trial III showed a large spread in moisture content due primarily to shortening the equalizing time and the occurrence of more honeycomb than might be acceptable in the marketplace. Moisture contents were in the acceptable range for Trial IV, but the interior darkening and incidence of honeycomb indicated this schedule was somewhat too high in temperature and not as acceptable as Trial Schedules I and V.

Summation and Projections

These trials established that yellow-poplar can be dried as 7/4 flitches at high temperatures and subsequently ripped into studs to meet National Grading Rules for STUD grade. The effects of growth stresses in these flitches from smaller logs appear to be minimized during high-temperature drying and equalizing. Flitches containing the pith, or with the pith just outside the flitch, often had growth stress splits which lengthened on drying (fig. 7). However, pieces one thickness or more from the pith had minimal end checking and showed virtually no residual growth stress on ripping.

To date, engineering (static bending) tests have not been completed to determine if a loss of strength results from this drying regime.

We suggest a schedule similar to Trial Schedules I and V to give the best results as judged by brightness of color, uniformity of moisture content, and levels of drying defects such as checking, collapse, and honeycomb.

In our small-scale lab equipment, about 27 to 28 hours at 235° F and an equalizing period of 46 to 48 hours at 200° F dry bulb gave good results.

This was confirmed with four loads dried later. Two loads with material from Tennessee and two with material from North Carolina, each containing about 440 board feet, were successfully dried with this schedule. The overall corrected average for the four loads was 11.0% MC with a range of flitch averages from 6.4 to 19.4%. Only three flitches exceeded the 15% limit that we were aiming for. All three flitches were in the same kiln load.

Equalizing times depend on several variables—our times are suggestions. Each operation will have to judge for itself the optimum length of equalizing time for its equipment and needs.

We would estimate a 20 to 25% increase for time in the kiln when using industrial kilns.

HIGH-TEMPERATURE KILN DRYING

High-temperature drying is defined as the drying of wood at dry-bulb temperatures of 212° F or higher. The commercial use of high-temperature drying techniques in the United States to date has been largely limited to softwood dimension. In the 1970's, technology was developed to successfully dry southern yellow pine at high temperatures, thus cutting kiln time from 3 days or more to 1 day or less.[1/]

Success with the process in softwood dimension has generated interest in applying the process to hardwoods. The early work with high-temperature drying of hardwoods began in Canada and Europe in the early 1950's with 1-inch lumber, with the traditional hardwood end uses in mind--furniture and flooring. Wengert's "Review of high-temperature kiln drying of hardwoods" gave an excellent review of published work from 1950 to 1972.[2/] Interest has continued in high-temperature drying for 1- to 1-1/2-inch hardwoods for both high-quality furniture and flooring and has also moved into the thicker dimensions to produce construction grade material, primarily studs.[3/] Utilizing high-temperature drying as a part of the SDR process is one such effort for hardwood construction materials.

1/ Koch, P. 1972. Utilization of the southern pines. U.S. Dep. Agric., Agric. Handb. 420, Vols. I and II.

1969. At 240° F southern pine studs can be dried and steam-straightened in 24 hours. So. Lbrmn. 219(2723):26-29.

2/ Wengert, E. M. 1972. Review of high temperature kiln drying of hardwoods. So. Lbrmn. 225(2794):17-21.

3/ Cassens, D. L. (Compiler). 1979. High-temperature drying of hardwoods. Proc. of a Symp., New Albany, Ind. Purdue University. 74 p.

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SDR

The SDR concept was developed at the Forest Products Laboratory as a means for reducing warp in structural lumber manufactured from low- and medium-density hardwoods. Warp, which is common in many hardwoods, is due to growth stresses formed in the tree as well as shrinkage differences in the wood. As lumber is sawed from hardwood logs, the stresses are released as warp. The problems of stress and warp are frequently worse in material from smaller diameter trees.

The principle involved in SDR warp reduction is based on the restraining effect of wide flitches, and the fact that drying stresses are the direct opposite of growth stresses. One hypothesis is that, in high-temperature drying, the lignin, (which bonds the stressed wood fibers together) plasticizes, and the fibers slip into a neutral or nonstressed position. After further drying or on cooling, the lignin rehardens, and the wood remains stress-free or nearly so.

SDR has been proven effective for use with yellow-poplar and is being tested for use with aspen. Two papers on yellow-poplar SDR studs are listed in the text and two are available on aspen.[1/] Further research on other species is planned for the future.

1/ Maeglin, R. R. 1979. Could S-D-R be the answer to the aspen oversupply problem? North. Logger and Timber Processor 28(1):24-25.

Maeglin, R. R. 1979. A new look at aspen studs. The Timber Producer Dec.(11):36.

U.S. Forest Products Laboratory.

***High-temperature drying of 7/4 yellow-popular flitches* for S-D-R studs, by R. Sidney Boone and Robert R. Maeglin. Madison, Wis., FPL, 1980.**

p. (*USDA For. Serv. Res. Pap.* FPL 365).

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